ANALYSIS OF MAXIMUM BITE FORCE CORRELATING TO FACIAL MORPHOLOGY AMONG EGYPTIAN DENTAL STUDENTS

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ABSTRACT

INTRODUCTION: Occlusal forces are considered a vital aspect of any dental treatment plan. Maximum occlusal force is intended to be correlated with facial dimensions, gender, and race.

OBJECTIVES: The purpose of this study was to analyze facial morphology and maximum occlusal bite among Egyptian dental students, in addition to determining the difference between males and females.

MATERIAL AND METHODS: Based on gender, 46 dental students were grouped into two distinct groups (23 males and 23 females). Each participant was photographed with a digital camera, and 2D Adobe Photoshop CS5 was utilized to calculate facial morphology according to their magnification ratio. Using a piezoresistive sensor (Flexiforce, Tekscan Inc., South Boston, USA), bite forces on both sides were measured three times. Maximum bite force and average occlusal force were recorded for both sides.

RESULTS: The mean value of the maximum occlusal force was 445.2 ± 66.8 N in males and 354.7 ± 81.19 N in females, with a highly significant difference. The majority of facial morphology variables were statistically greater in males than females, which was clarified through the results of the research. However, the correlation between male facial morphology and the bite was statistically significant.

CONCLUSIONS: In terms of bite forces and facial morphology, males have higher values for most of the parameters and a significant correlation between them.

KEYWORDS: bite force, facial morphology, gender, Egyptian, and digital photogrammetry

RUNNING TITLE: maximum bite force correlating to facial morpholgy among egyptian students

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INTRODUCTION

The correlation between occlusal bite forces and face dimensions, gender, race, and morphological status has been investigated in many previous studies. This relationship should be considered in the treatment plan for any restorative or prosthetic procedure for long success rate (1-3).

Occlusal force is the force generated by the synchronization of the various masticatory system parts (muscles, bones, and teeth) in function and parafunctional behaviors. According to the actions of the masseter, tymporalis, medial, and lateral pterygoid muscles, as well as the biomechanical jaw and biomechanical reflex, the bite force is also regarded as a significant sign of the health of the stomatognathic system (1).

Maximum occlusal force values are still controversial. This can be attributed to anatomical and physiological factors that include craniofacial morphology, age, gender, race, physical configuration, type of occlusion, and food culture. Moreover, it is related to the device used,
interocclusal separation, head posture, unilateral or bilateral, and position of the measurement in the arch. Occlusal force varies between anterior and posterior teeth, and the first molar area shows the highest magnitude. Alam (2020) stated that subjects with malocclusion have less ability to exert force than those with normal occlusion (4).

Borelli invented the first gnathodynamometer, measuring occlusal forces, in 1681. In this device, different weights were attached to a rope that was held by the molar teeth in the maximum bite position. Many scientists have investigated this topic since then, and many equipments have been designed for this purpose (5). One of the recent devices tested to be valid for occlusal bite measurements is the piezoresistive sensor. The sensor is composed of two layers of a substrate; when a load is applied to the surface, the resistance decreases, and these changes

are converted into force magnitude using computer software (6).
Individual differences can be found in the pattern of human facial growth and development and according to gender. Vijeta (2019) reported that long-faced subjects showed significantly lower maximum bite forces than those with standard vertical facial dimensions (1). Craniofacial morphology includes total and lower anterior facial height, bizygomatic width, mandibular inclination, and gonial angle. For the measurement of craniofacial dimensions without subjecting patients to unnecessary radiation, standardized facial photographs are considered a trusted clinical and scientific tool (7).
Gender difference is considered the most important factor affecting bite force (2, 3, 8). The intensity of bite force exhibits an increase with age. The gender effect on jaw morphology can be seen in the higher biting force values in males, but this correlation is not significant in young children (9, 10). On the other hand, the relationship between the maximum voluntary biting force and body composition is weak.
Previous research has examined how many variables, including gender, weight, height, and the occlusal scheme, affect masticatory loads. However, there is a lack of data on occlusal force concerning vertical facial patterns among the Egyptian population. This study will correlate maximum bite force to facial morphology among Egyptian dental students. The null hypothesis was that there is no correlation between facial morphology and occlusal bite, nor is there a difference between genders.

MATERIAL AND METHODS

Ethical Considerations: The Faculty of Dentistry Research Ethics Committee at the University of Alexandria granted approval (Code No. 0269-07/2021). The consent form has been signed by each participant. In addition, they obtained assurances regarding the privacy of the collected data, which will only be accessible to the research team and used for study-related purposes. Every participant volunteered their time. For the use of their photos, they didn't ask for any money or other kind of payment.
Study design: The research was conducted at the Faculty of Dentistry at the University of Alexandria. The study was cross-sectional, following STROBE checklists (11), and the sample included 46 students between the ages of 18 and 24 (23 males and 23 females).
Criteria for the selection: Male and female dental students between the ages of 18 and 24 of Egyptian descent. There's no apparent facial asymmetry (12). Class I skeletal pattern with no orthodontic treatment (13). All teeth are present, with the exception of the third molars (14). Absence of cavities or fillings in the first permanent molars. Signing the consent form. While subjects who participated in previous facial trauma or plastic surgery, class II or III skeletal pattern in occlusion or malocclusion were excluded. This includes thumb-sucking and tongue-thrusting. Permanent first molars are extracted, heavily restored, or a posterior crossbite is present (15). Active periodontal disease accompanying mobile teeth. Men with full beards have been excluded from this study because photographic identifiers could not be determined. Participants who objected to having their picture taken were also not included in the study.
History and Clinical Examination: The medical record of the participant was reviewed to rule out facial injuries, facial plastic surgery, or orthodontic therapy. Extraoral and dental assessments were performed to rule out the presence of any malocclusion, restorations, prosthetic crowns, tooth wear, active periodontal diseases, or orthodontic appliances.
Maximum Occlusal Force: The maximum occlusal force was recorded for every participant in one session using a piezoresistive sensor (Flexiforce B201 ELF system, Tekscan Inc., South Boston, USA). Force is transformed into electrical signals by load cells (transducers) and an electronic device used to identify changes in the sensor's resistance. Utilizing ELF software on a computer, changes in resistance were converted into newtons (Fig.1). The FlexiForce sensor B201 is a flexible and ultra-thin printed circuit. At the end of the sensor, the "active sensing area" is a circle with a diameter of 9.5 mm and a thickness of 0.2 mm. For concentrating forces in the sensor's center, load concentrators with a 7 mm diameter and 0.7 mm thickness (Tekscan Inc., South Boston, USA) were utilized (Fig.2). As an infection control measure, the sensor was wrapped in a plastic sleeve. The sensor was calibrated using a universal testing machine (Shimadzu, Kyoto, Japan).
Before the occlusal force recording, the subjects were seated upright without a headrest, and the Frankfort plane was almost parallel to the floor. They were informed to bite as firmly as possible on the sensor. The maximum occlusal forces were measured three times on each side at the location of the first molar, with a two- to three-minute interval between each measurement. From these recordings, the maximum occlusal force (MOF) and the average bite measurement of force on both sides were analyzed.
Standardization of photographic strategies: To assess correct facial proportion, the participant must be examined in a physical head position that ensures the Frankfort horizontal line is parallel to the floor so as to keep the head from tilting; this allows the patient to be placed in a proper alignment, demonstrating the stability of the photographic reproduction (16). A

digital DSLR camera (Canon 800D) was supported by a tripod with a variable height. All frontal images of faces were standardized to have a focus distance of one meter between the camera's lens and the subject's face. In order to calibrate the measurements, a ruler attached to a headband was attached to each participant's forehead. Each participant had two photographs taken: the front one with no smile and a lateral view with the right side of the face directed by the investigator.

Photographic Analysis: Facial Soft Tissue Landmarks: soft tissue landmarks were marked using adhesive points (17) (Fig. 3).

Nasion (n): the intersection of the nasofrontal sutures in the midline.

Zygion (zy): the most lateral soft tissue point on the zygomatic arch.

Subnasale (sn): the median point at the junction between the lower border of the nasal septum and the philtrum area.

Menton (me): the lowest median point of the chin.

The Linear Facial Measurements: Photographs were analyzed (18) and according to the magnification equation, the following parameters were calculated using Adobe Photoshop CS5. (Fig. 4,5)

$$\frac{\text{Length of prameter (photograph)}}{\text{length of parameter (real)}} = \frac{\text{1 cm scale (photograph)}}{\text{1 cm}}$$

Bizygomathic width (BZW): The distance between the bilaterally located zygion landmarks.

Total anterior facial height (TAFH): The distance between the nasion and menton.

Lower anterior facial height (LAFH): The distance between the subnasal to menton.

Reliability

Intra-examiner reliability was tested to confirm the degree of agreement between measurements. The mean ICC score was 0.86, which indicates good reliability, and statistically no difference was found between measurements.

Statistical Analysis

Normality was checked using Shapiro Wilk test and Q-Q plots. All variables were normally distributed, thus mean, standard deviation, and 95% confidence interval (CI) were used for data presentation. Using an independent t test, male and female comparisons were made. The correlation between parameters was done using Pearson correlation test. All tests were 2-tailed and the significance level was set at p value<0.05. Intraexaminer reliability was done using Intraclass Correlation Coefficient (ICC). Data were analyzed using IBM SPSS version 23, Armonk, NY, USA.

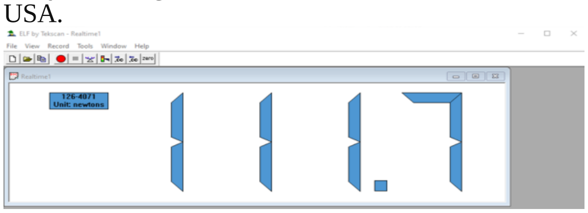

Fig.1: ELF software display forces in newtons digitally on computer.

Fig.2: Flexiforce sensor B201 and Load concentrators

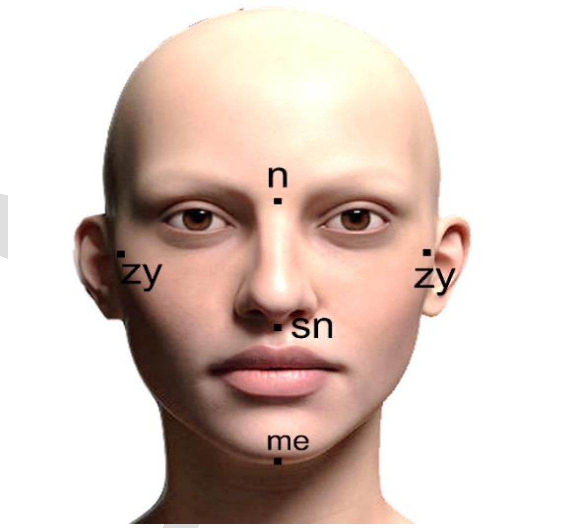

Fig.3: Facial soft tissue landmarks: Nasion (n), Zygion (zy), Subnasale (sn) and Menton (me)

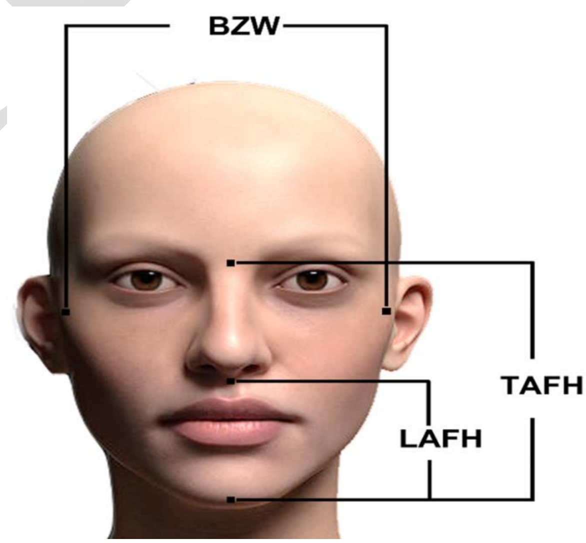

Fig.4: Frontal view of Linear facial landmarks

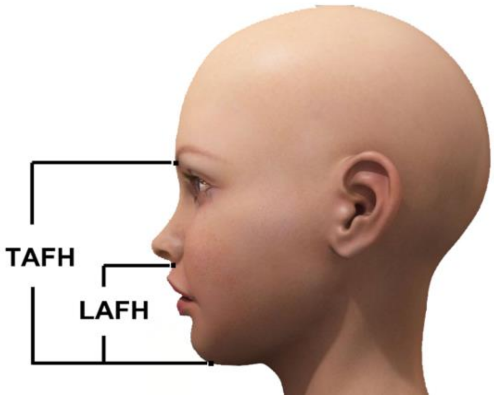

Fig.5: Lateral view of Linear facial landmarks

RESULTS

Maximum bite force was higher in males (Table 1). Male groups had a mean maximum bite force of 445.22 ± 66.80 N (range: 340 to 572 N), while female groups had a mean maximum bite force of 354.65 ± 81.19 N (range: 240 to 572 N).

The vast majority of facial morphology parameters were statistically more prevalent in males than females, with the exception of indices in which the difference was not significant. This BZW of males was 13.13 ± 0.68 cm and that of females was 11.96 ± 0.74 cm, with a highly significant difference. Males and females had TAFH and LAFH measures of 10.66 ± 0.60 cm, 5.61 ± 0.44 cm, and 10.09 ± 0.81 cm, 5.15 ± 0.49 cm, respectively (Table 2).

For the correlation between facial morphology and maximum bite force, males revealed statistically significant differences between MOF and BZW and BZW/TAFH. However, no significant correlation was found among females (Table 3).

Table 1: Comparison of bite force between males and females

	Males (n=23)	Females (n=23)	Mean difference	95% Confidence Interval		*p* value
	Mean ± SD			Upper limit	Lower limit	
Right	355.81 ± 66.33	266.00 ± 91.13	89.81	42.45	137.18	<0.0001*
Left	288.58 ± 61.51	219.88 ± 54.83	68.70	34.07	103.32	<0.0001*
Overall	322.20 ± 52.89	242.94 ± 62.69	79.25	44.79	113.72	<0.0001*
Maximum	445.22 ± 66.80	354.65 ± 81.19	90.57	46.38	134.75	<0.0001*

*Statistically significant at *p* value≤0.05

Table 2: Comparison of facial morphology measurements between males and females

	Males (n=23)	Females (n=23)	Mean difference	95% Confidence Interval		*p* value
	Mean ± SD			Upper limit	Lower limit	
BZW	13.13 ± 0.68	11.96 ± 0.74	1.17	0.75	1.59	<0.0001*
TAFH	10.66 ± 0.60	10.09 ± 0.81	0.57	0.14	0.99	0.010*
LAFH	5.61 ± 0.44	5.15 ± 0.49	0.46	0.18	0.74	0.002*
TAFH/ LAFH	1.91 ± 0.11	1.97 ± 0.12	-0.06	-0.13	0.01	0.077
BZ/TH	1.24 ± 0.09	1.19 ± 0.07	0.05	0.00	0.09	0.059
BZ/LH	2.36 ± 0.22	2.34 ± 0.22	0.02	-0.11	0.15	0.776

*Statistically significant at *p* value≤0.05

Table 3: Correlation between facial morphology measurements and maximum bite force in males and females

	Males (n=23)		Females (n=23)		Overall (n=46)	
	r	*p* value	r	*p* value	r	*p* value
BZW	0.446	0.033*	0.031	0.888	0.477	0.001*
TAFH	-0.379	0.074	0.124	0.574	0.147	0.329
LAFH	-0.180	0.412	-0.015	0.945	0.174	0.247
TAFH/LAFH	-0.169	0.442	0.168	0.444	-0.117	0.438
BZ/TH	0.592	0.003*	-0.152	0.489	0.326	0.027*
BZ/LH	0.355	0.096	0.009	0.967	0.162	0.283

*Statistically significant at *p* value≤0.05

DISCUSSION

Male and female participants were selected between the ages of 18 and 24 (mean 22.7 ± 1.1 years). Because of the reality that people usually maintain the same facial dimensions until the age of 25, and to reduce the consequences of any remaining skeletal growth, the majority of facial growth normally ceases between the ages of 16 and 17 years (19). The occlusion has also been established at this stage, regardless of the eruption of the third molar (20). Occlusal bite forces tend to rise during different developmental stages but level off after puberty. There is proof that they peak around the age of 12 and then stabilize around the age of 14 (21).

In accordance with a previous study (2), the mean maximum occlusal force in the male groups was 445.2 ± 66.8 N, and in the female groups it was 354.7 ± 81.19 N. These forces are lower than those reported by other researchers (3, 9, 22). The fact that various populations have different biting forces, which may be related to food cultures and facial morphology, may, however, explain this. Also, different equipment and techniques can lead to different outcomes.

The most influential factor in occlusal bite forces is gender. There was a statistically significant difference between the sexes (p value ≤ 0.05), as supported by numerous prior studies (2, 3, 8, 9, 22). Compared to women, men's masseter muscles have type 2 fibers with greater diameters and wider cross-sectional areas; the composition of the fibers may be influenced by hormone changes (23). According to results from another study, females have a much lower pressure pain threshold at maximum biting, and pressure pain intolerance may be the cause of the lower bite force in females(24). Before measuring, however, each subject was informed to bite as hard as possible and trained. Others, however, have stated that there is no difference between men and women (1, 25).

In the present study, a majority of facial measurements demonstrated significant gender variations. Males had higher BZW, TAFH, and LAFH, which was in accordance with previous research on the Egyptian population (26-28). This can be explained by considering that human growth is regulated by both genes and hormones and that males have longer growth periods than females, resulting in greater measurements (29). However, these studies utilized a sliding scale for linear measurement rather than standard facial photographs. This can explain the small differences in this study's results.

On the other hand, the results for the other races are still controversial. Baik et al. (2007) (30) found no statistically significant variance in LAFH in the Korean sample. Also, in accordance with Karaca et al. (2012) (31), there was no statistical difference between males and females in the BZW among the Turkish sample. This can be explained through numerous methods of measurement and equipment, sample size, age range, and sample selection methodology.

Many research investigations have examined the relationship between facial morphology and maximum bite force. Nevertheless, the diagnostic procedures and methodologies used in the majority of these studies vary. As a result, care must be taken when comparing the various bite force measurements.

As a tool for measurement in this study, a piezoresistive sensor (Flexiforce ELF system) was utilized. This system's thickness is less than 2 mm, making it comfortable, easy to use, and inconspicuous to the subject's mastication dynamics. Furthermore, the Flexiforce ELF system is digitalized, and measures are displayed on a computer screen for a more reliable data recording system.

Based on the results, it was determined that BZW and BZW/TAFH had a positive correlation with occlusal force only in males, whereas none of the parameters had a significant correlation with occlusal force in females. In other words, men with a larger head circumference had a stronger occlusal bite. Similarly, Bonakdarchian et al.(32) reported that subjects with square faces had a stronger bite force. Using strain-gauge transducers, they measured the relationship between face forms and maximum molar bite force based on standardized digital photographs of the face.

However, a limitation of our research was the random selection of study participants. This may explain the absence of a correlation in females without focusing on different facial morphology or the small sample size. Our research sample was comprised of dental students from Alexandria Dental Faculty. The null hypothesis was rejected, as MOF showed a significant positive correlation with BZW and the ratio BZW/TAFH in males. Also, males showed higher values of facial morphology and MOF than females, which was statistically significant.

CONCLUSION

Studying the facial morphology of humans is one of the most interesting fields of cosmetic and anthropometric research. In most parameters, males have higher values in facial morphology and bite forces. However, a larger sample size is needed to analyze the correlation between facial morphology and maximum bite in females.

CONFLICT OF INTEREST

The authors reveal that they have not experienced any financial or personal conflicts of interest.

FUNDING STATEMENT

There has not been any specific funding received by the authors for this work.

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